DEVELOPMENT OF USER INTERFACE FOR VIBRATION MEASUREMENT

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ABSTRACT

Today's industry uses increasingly complex machince, some with extremely demanding performance criteria. Failed machine can lead to economic loss and safety problems due to unexpected production stoppages. Fault diagnosis in the condition monitoring of these machines is crucial for increasing machinery availability and reliability.Fault diagnosis of machinery is often a difficult and daunting task. To be truly effective, the process needs to be analysis to reduce the reliance on manual data interpretation. It is the aim of this research to analysis this process using data from machinery vibrations. This thesis focuses on the development, and application of an analysis diagnosis procedure for rolling elements bearing faults. Rolling element bearings are representative in most industrial rotating machinery. Besides, these elements can also be tested economically in the laboratory using relatively simple test rigs.Novel moden signal processing method were applied to vibration signals collected from rolling elements tests. This included time-frequency signal processing techniques such as FFT.

ABSTRAK

Pada zaman sekarang, industri menggunakan mesin yang semakin kompleks, ada segelintir dengan amat menuntut kriteria prestasi. Kegagalan mesin boleh membawa kepada kerugian ekonomi dan masalah keselamatan yang disebabkan oleh penamatan pengeluaran yang tidak dijangka. Diagnosis kerosakan dalam pemantauan keadaan mesin ini adalah penting untuk menyemak ketersediaan jentera yang semakin meningkat dan kebolehpercayaan.Diagnosis kerosakan jentera sering sukar dan merumitkan. Untuk keberkesanan, proses analisis perlu untuk mengurangkan pergantungan kepada interpretasi data pengguna. Ia adalah matlamat kajian ini untuk menggunakan proses analysis data dari getaran jentera. Tesis ini memfokuskan kepada pembangunan dan aplikasi prosedur diagnosis analisis untuk unsur-unsur berputar mengandungi kesilapan. Galas unsur berputar adalah paling banyak digunakan dalam perindustrian. Selain itu, elemen-elemen ini juga boleh diuji ekonomi di makmal menggunakan pelantar ujian yang agak mudah.Novel moden kaedah pemprosesan isyarat digunakan isyarat getaran dikumpul daripada ujian unsur bergolek. Ini termasuk teknik masa-kekerapan pemprosesan isyarat seperti FFT.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF ABBREVIATION

MAX	Measurement and Automation Explorer
RPM	revolution per minute
GUI	graphical user interface
FFT	fast fourier transform
AC	alternating current
CPM	cycles per seconds
Hz	Hertz
N	number of sample
DAQ	data acquisition
LED	light emitter diode
μ	micro
π	Pi
σ	sigma
$\ddot{x}$	acceleration
$\dot{x}$	velocity
x	displacement
n	rotational speed
Sa/s	samples per second

CHAPTER 1

INTRODUCTION

1.1 PROJECT BACKGROUND

The importance of vibration measurements for maintenance services in industries.
In this day when manufacturers increase their operational profits they assume in the first place that this is because of a good marketing plan. But they forget that an effective maintenance budget is the fact that keeps them on top of the game.

This thesis work will explain all the common maintenance practices used by industries in our days and their economical advantages. The main focus of the thesis is to demonstrate the importance of vibration analysis in detecting failure occur in machining. How vibration measurements are performed in a real world scenario is also part of the thesis.
Of all the parameters that can be measured in the industry, not one of them contains as much information as the vibration analysis. The vibration analysis is one of the most important tests for understanding what is happening in a machine. The level of vibration and the pattern of the vibration tell us something about the internal condition of the rotating component. The vibration pattern can tell us if the machine is out of balance or out of alignment. Also faults with rolling elements and coupling problems can be detected through vibration analysis.

When performing vibration measurements there are four phases involved: detecting if a problem exists, performing an analysis to diagnose the severity of the problem, determining why the problem took place and verifying that the problem is solved once the machine is repaired.

If we can interpret the data obtained from the vibration analysis in a correct way and perhaps change the way the machine is operated or maintained, the machine will become more reliable in the future making the overall process more profitable.

User interface design or user interface engineering is the design of appliances, machines, software applications. Good user interface design facilitates finishing the task at hand without drawing unnecessary attention to itself. Graphic design may be utilized to support its usability. The design process must balance technical functionality and visual elements (e.g., mental model) to create a system that is not only operational but also usable and adaptable to changing user needs. The user interface, in the vibration measurement field of human–machine interaction, is the space where interaction between humans and machines occurs. The goal of interaction between a human and a machine at the user interface is effective operation and control of the machine, and feedback from the machine which aids the operator in making operational decisions. GUIs generally provide users with visual feedback about the effect of each action GUIs allow users to take full advantage of the powerful *multitasking* capabilities of modern operating systems by allowing such multiple programs to be displayed simultaneously. The result is a large increase in the flexibility of analysis in vibration measurement.

1.2 PROBLEM STATEMENT

When a machine does not perform a required function as a result of an incident, this can be described as a failure. In most of the cases failures can be anticipated through a good maintenance plan, but the possibility of unpredictable critical failures is always present. Bearing are single largest cause of machine failures. A continued stress on the bearings causes the fatigue failures, usually at the inner or outer races of the bearings. These failures result in rough running of the bearings that generates detectable vibrations and increased noise levels. Good user interface design facilitates finishing the task at hand without drawing unnecessary attention to itself. The graphical user interface can detect the bearing failure by analysis method. It can determine the bearing life span and level of failure occur. By using an effective graphical user interface, the bearing failure can be detected and reduce it.

1.3 PROJECT OBJECTIVE

For this project, a single objective to be achieved as listed below;

i. To develop an user interface for vibration measurement (detect the bearing failure occur)

1.4 PROJECT SCOPE

The scope of this project are listed as follows;

i. Study the fundamental of vibration measurement & common parameters that used for vibration measurement
ii. Design a graphical user interface for vibration measurement
iii. Program the user interface by using Dasylab software

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

Vibration measurements give us the information needed to understand why problems have occurred. If we can interpret the data obtained in a correct way and perhaps change the way a machine is operated or maintained, the machine will become more reliable in the future making the overall process more profitable.

Therefore by including vibration measurements into our maintenance plan we can save money and in most of the cases improve the product quality

2.2 FUNDAMENTAL OF VIBRATION

Vibration can be described as the mechanical oscillation about an equilibrium point. In case that you are measuring vibration from the bearing of a machine, you are measuring the response of the bearing housing to the forces generated inside the machine. Those forces relate to all of the rotating elements: the shaft, the balls in the bearing, and the blades on the fan, plus the vibration coming from the process and surrounding machines (Mobius Institute 2005, 21).

2.2.1 Displacement, x

Displacement measurement is the distance or amplitude displaced from a resting position. The SI unit for distance is the meter (m), although common industrial standards include mm and mils. Displacement vibration measurements are generally made using displacement eddy current transducers.

$$x(t) = X \cos\ (2\pi f t - \emptyset_x) \qquad (2.1)$$

2.2.2 Velocity, ẋ

Velocity is the rate of change of displacement with respect to change in time. The SI unit for velocity is meters per second (m/s), although common industrial standards include mm/s and inches/s. Velocity vibration measurements are generally made using either swing coil velocity transducers or acceleration transducers with either an internal or external integration circuit.

$$v(t) = (2\pi f t)\, X \cos\ (2\pi f t - \left(\emptyset_x - \frac{\pi}{2}\right)) \qquad (2.2)$$

2.2.3 Acceleration, ẍ

Acceleration is the rate of change of velocity with respect to change in time. The SI unit for acceleration is meters per second2 (m/s2), although the common industrial standard is the g. Acceleration vibration measurements are generally made using accelerometers.

$$a(t) = (2\pi f)V \cos(2\pi f t - \left(\emptyset_v - \frac{\pi}{2}\right)) = (2\pi f)^2 X cos(2\pi f t - (\emptyset_x - \pi)) \qquad (2.3)$$

In this analysis, the sensor accelerometer is used to obtain the reading of acceleration. The fundamental of vibration discuss about acceleration, velocity and displacement with respectively equation. The acceleration is most importance in this analysis, by obtaining the reading to simulate in graphical user interface to show failure of bearing .

2.3 FUNDAMENTAL OF SIGNAL ANALYSIS

2.3.0 Sampling rate

Defines the number of samples per unit of time (usually seconds) taken from a continuous signal to make a discrete signal. For time-domain signals, the unit for sampling rate is hertz (inverse seconds, 1/s, s^{-1}), sometimes noted as Sa/s (samples per second). The inverse of the sampling frequency is the sampling period or sampling interval, which is the time between samples.

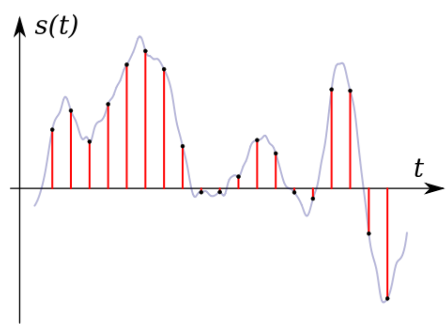

Figure 2.0 Sampling Rate Graph

(Source; Bendat, Julius S. and Piersol, Allan G.,*"Random Data: Analysis and Measurement Procedures"*,Wiley-Interscience,New York, 1971.)

2.3.1 Block Size

Block size in transform coding is a tradeoff between time and frequency resolutions. Although not always explicitly pointed out, a variable block size is a local adaptation aiming to obtain a better projection of the signal on the time-frequency plane. The block size dictates the tradeoff. Larger blocks mean coarser time resolution and narrower subbands, whereas small blocks mean better time localization and worse frequency resolution. Block transforms of variable sizes can be easily applied to images as the problem is simplified to a tiling of the image into rectangular regions

2.3.2 Fast Fourier Transfrom (FFT)

A time domain format can be converted to frequency domain data by using mathematical transform technique called as '(Fast) Fourier Transform', which is named after Jean Fourier. FFT or advanced methods of it allows vibrations analyst to see discrete frequency peaks of vibrating components clearly. A frequency-domain plot is either displacement or velocity or acceleration versus time, unlike amplitude versus time in time domain format

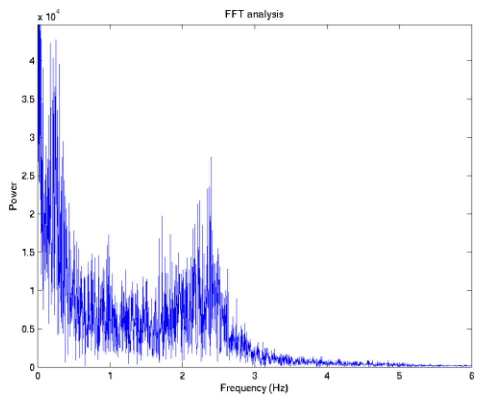

Figure 2.1 FFT Graph

(Source; Roth, P., *"Digital Fourier Analysis"*,Hewlett-Packard Journal, June 1970.)

2.3.3 Frequency Domain

A frequency domain format of vibration profile is a combination of frequencies related to circular rotations or linear movements of parts of machines. Hence these vibration profiles can be considered as a multiple of fundamental frequencies of the parts, equipment or the system. Such frequencies can be expressed in terms (their units are) revolutions per minute

(RPM) or cycles per minute (CPM) or cycles per second (Hertz). To analyze the operation condition of the machine in frequency domain, these fundamental frequencies must be determined first

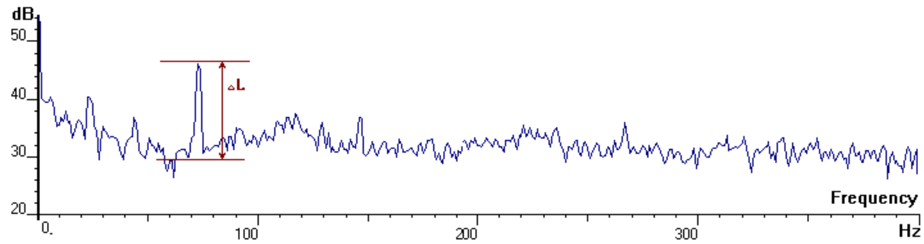

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Figure 2.2 Frequency Domain Graph

(Source; Cooley, J.W. and Tukey, J.W., *"An Algorithm for the Machine Calculation of Complex Fourier Series"*, Mathematics of Computation, Vo. 19, No. 90, p. 297,April 1965.)

2.3.4 Time Domain

In the time domain format the vibrations data is plotted as amplitude versus time. Examples of basic formats are shown in previous figures and example for a real time industrial system is shown in following figure.

Time domain formats are usually used for reciprocating and linear movement machineries.

They are also useful in overall evaluation and analysis of a system to study subtle changes in operations. On the flip side, to interpret the data from time domain efficiently, is quite a tedious task. The vibrations data in time domain format is complexly integrated. It represents the mixed spectrum of all the sources of the system at a particular instant of time. Hence, it is very difficult to find out the specific spectrum of a particular source

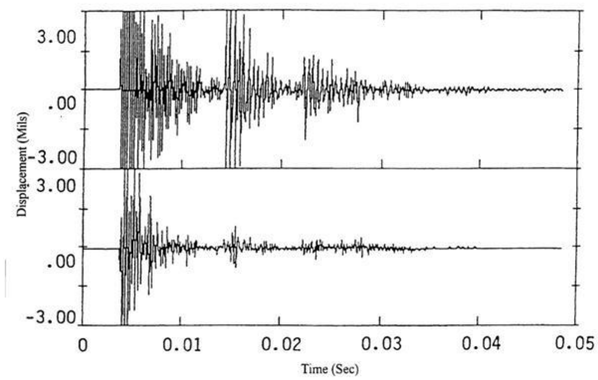


Figure 2.3 Time Domain Graph

(Source; Otnes, R.K. and Enochson, L.,*"Digital Time Series Analysis"*, John Wiley, 1972.)

2.4 Standard Parameter of Vibration Measurement

2.4.1 Variance, μ

The variance is a measure of how far a set of numbers is spread out. It is one of several descriptors of a probability distribution, describing how far the numbers lie from the mean (expected value). In particular, the variance is one of the moments of a distribution. This parameter shows the mean value of analysis data of bearing failure.

$$\mu = \int x\, f(x)\, dx \tag{2.4}$$

2.4.2 Standard deviation, σ

It shows how much variation or "dispersion" exists from the average (mean, or expected value).probability distribution is the same as that of a random variable having that distribution. This parameter show the average mean value of analysis data of bearing failure.

$$\sigma = \sqrt{\int_{\mathbf{X}} (x-\mu)^2 \, p(x) \, dx}, \quad \text{where} \quad \mu = \int_{\mathbf{X}} x \, p(x) \, dx, \tag{2.5}$$

2.4.3 Root Mean Square (RMS)

The root mean square (RMS) value of a vibration signal is a time analysis feature, which is the measure of the power content in the vibration signature. This features is good for tracking the overall noise level, but it will not provide any information on which component it failing. It can be very effective in detecting a major out of balance in rotating system. This parameter show the noise level of analysis data of bearing failure.

$$f_{\mathrm{rms}} = \lim_{T \to \infty} \sqrt{\frac{1}{T} \int_0^T [f(t)]^2 \, dt}. \tag{2.6}$$

In the analysis, the variance is used to detect the mean value of bearing failure meanwhile standard deviation is used to detect the average mean value of bearing failure. Both of this parameters shows the level of bearing failure occur in each revolution. The RMS is used to detect the noise level in bearing failure. This parameter is used to shows the noise level that occur each revolution.

2.5 BASIC PROGRAMMING

A *program* is a set of step-by-step instructions that directs the computer to do the tasks you want it to do and produce the results you want. Programming helps you understand computers. The computer is only a tool. If you learn how to write simple programs, you will gain more knowledge about how a computer works. Writing a few simple programs increases your confidence level. Many people find great personal satisfaction in creating a set of instructions that solve a problem. Learning programming lets you find out quickly whether you like programming and whether you have the analytical turn of mind programmers need. A set of rules that provides a way of telling a computer what operations to perform is called a programming language. In general, BP converts problem solutions into instructions for the computer. That is, the programmer prepares the instructions of a computer program and runs those instructions on the computer, tests the program to see if it is working properly, and makes corrections to the program. The programmer also writes a report on the program. These activities are all done for the purpose of helping a user fill a need, such as paying employees, billing customers, or admitting students to college.

The programming activities just described could be done, perhaps, as solo activities, but a programmer typically interacts with a variety of people. For example, if a program is part of a system of several programs, the programmer coordinates with other programmers to make sure that the programs fit together well.

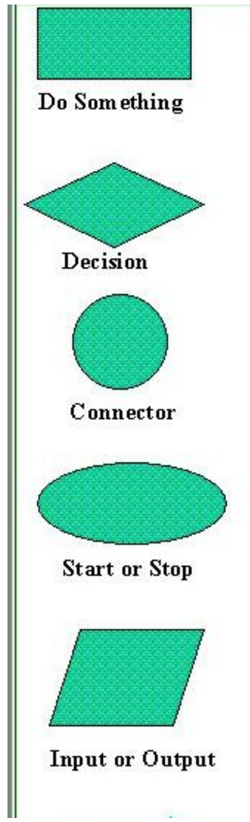


Figure 2.4 of Flow Chart Icon

2.6 DASYLAB SOFTWARE

Sensitive instruments and machines such as integrated circuit wafer scanners often contain motion systems that control displacements of one micron or less. This dynamic makes the machines particularly sensitive to even minute environmental vibrations, so it's essential that the equipment contains high stiffness support frames to handle all incidental shock and vibration programs for vibration testing based on the DASYLab software package. Vibration testing is a search for the source of a noise, shake, or vibration. Engineers measure the frequency of the vibration and look for components that are rotating at the same frequency at that particular vehicle speed to determine the source of the sound or vibration, such as a tire, the transmission, or the engine The engineers also used FFT equipment that came in large boxes and were particularly difficult to manage on the factory floor. With increasing vehicle production, QA needed to modernize and replace the X-Y plotters and FFT boxes to accelerate the process, save more data, and distribute the data faster

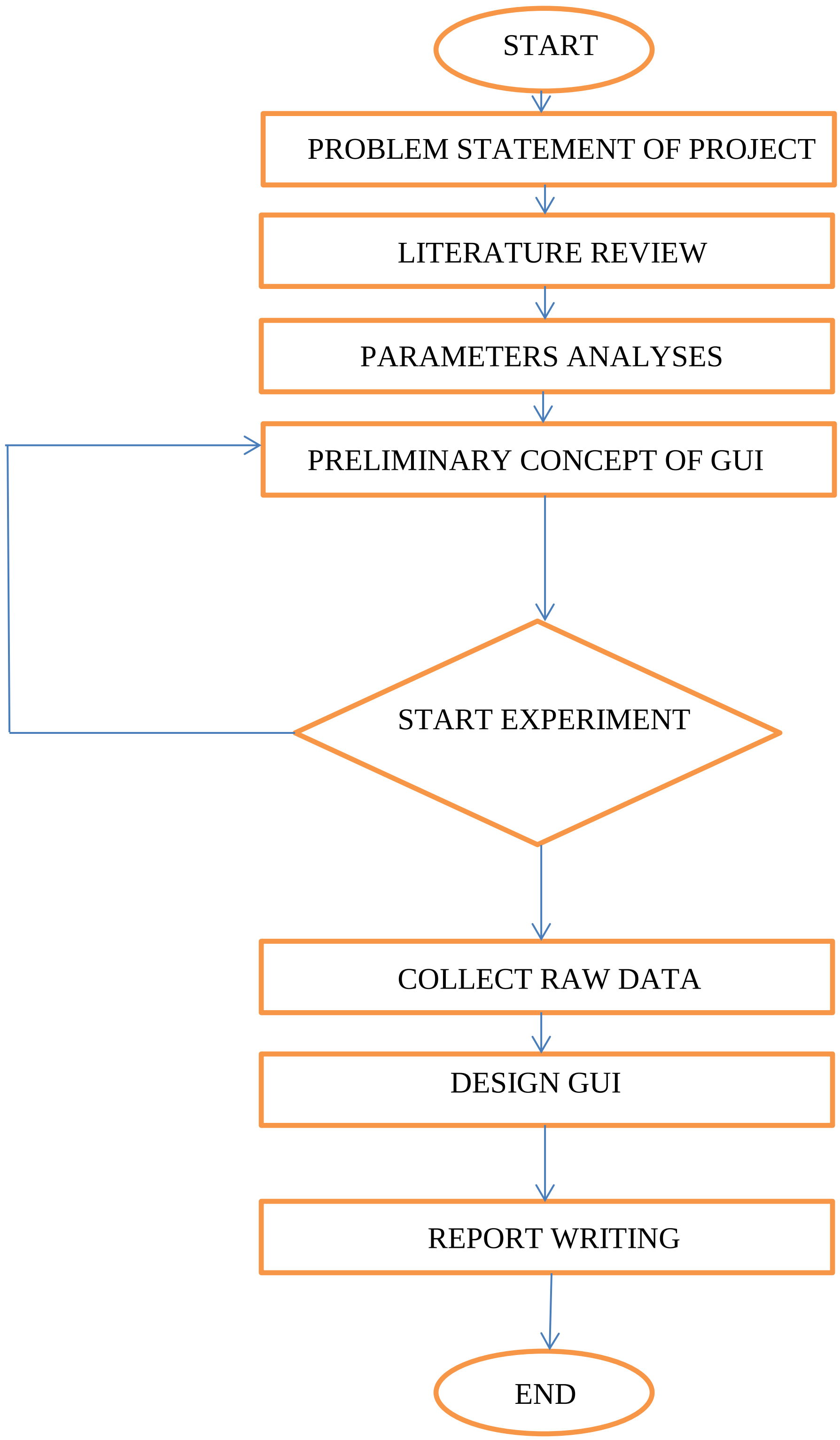
CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

This section will briefly describes the way of analysis the data from experiment with the material selection for making graphical user interface to determine the best and accurate result for this study. The variables and performance parameters also will be explained other than problem setup. So, all the value data from the experiment will be obtain for bearing failure and finally are able to suggest the suitable graphical user interface.

3.2 FLOW CHART



3.2.1 Problem Statement of Project

The main problem is the failure occur in machining especially bearing. The objective is develop an user interface to overcome this failure occur.

3.2.2 Literature Review

The literature review contains of fundamental of vibration, fundamental of signal analysis, standard parameters of vibration measurement, basic programming and dasylab software. This literature review be a guideline to obtain the analysis and GUI.

3.2.3 Parameter Analysis

The parameter of this analysis are variance, standard deviation and RMS. It had been studied from fundamental and get references from the journal to continue this project.

3.2.4 Preliminary Concept of GUI

Before using the real bearing test rig, the analysis used generator as medium to collect the data and simulate the software. The result of this analysis been used to generate three different concept of GUI.

3.2.5 Start Experiment

As the result from preliminary concept been approved, the analysis start with real bearing test rig. The experiment starts with using sensor, A/D converter and data acquisition.

3.2.6 Collect Raw Data

From the experiment, the raw data generates from the bearing failure is recorded. Generates the raw data into block size, FFT , and filter to simulate the failure and compare it .